Stantec

Memo

To:	Terri Fraser, P.Eng. Technical Manager Northern Pulp Nova Scotia Corporation PO Box 549, Station Main New Glasgow, NS B2H 5E8	From:	Sam Salley Stantec Consulting Ltd. 102-40 Highfield Park Drive Dartmouth, NS B3A 0A3
File:	121416276	Date:	September 25, 2019

Reference: Estimate of Sediment Transport of the NPNS Treated Effluent

The Replacement Effluent Treatment Facility Project proposed by Northern Pulp Nova Scotia Corporation (NPNS) was registered on February 7, 2019 for environmental assessment (EA) as a Class 1 undertaking pursuant to Part IV of the *Environment Act* and the Environmental Assessment Regulations.

On March 29, 2019, the Minister of Environment released a decision concerning this review. The Minister has determined that the EA Registration Document (EARD) is insufficient to make a decision on the Project, and a Focus Report is required in accordance with clause 13(1)c of the Environmental Assessment Regulations, pursuant to Part IV of the *Environment Act*.

NPNS is required to submit the Focus Report within one year of receipt of the Terms of Reference (TOR), which were issued by Nova Scotia Environment on April 23, 2019. Section 4.3 of the TOR for the preparation of the Focus Report identified the requirement "to provide results of sediment transport modeling work to understand the impacts of potential accumulation of sediments within near field and far field model areas. This should include chemical and physical characterization of the solids proposed to be discharged by NPNS as well as a discussion of how these solids will interact with the marine sediments and what the potential impact will be on the marine environment as a result."

Sediment transport is the movement of solid particles in a water column driven by gravity in vertical direction and by currents in horizontal direction. This memo provides estimation of sediment transport in the area near the proposed outfall location for the treated effluent based on measured and calculated values for a particle movement as well as information derived from other pulp mills.

The transport of suspended sediment in the water column can be estimated by the settling velocity of the sediment particles and the current velocities. Several theoretical and empirical formulas have been developed to predict the settling velocity for different particle sizes as well as various conditions (e.g., Reynolds Number Re). According to the particle size analysis (PSA) from Howe Sound Pulp and Paper's treated effluent (UBC, June 2019), a Paper Excellence kraft pulp mill in British Columbia, the sediment grain size is expected to have the distribution characteristics of D_{50}=15.3 µm (the grain size that 50% of sediment volume has a smaller value) and D_{90}=58.8 µm (the grain size that 90% of sediment volume has a smaller value) respectively. The PSA analysis for the treated effluent from the Crofton Mill (a second Paper Excellence mill located in BC that also produces kraft pulp and paper) indicates the particle size characteristics of D_{50}=12.6 µm and D_{90}=74.6 µm (UBC, July 2019). The Howe Sound and Crofton mills are both kraft mills with activated sludge treatment (AST) systems for treating their effluent, which is also being proposed for NPNS's replacement effluent treatment facility project. The treated effluents from the Howe Sound and Crofton mills indicate that the sediment in the effluent contains predominantly fine particles.

The settling velocity (W_S) can be estimated by an empirical formula of Stokes Law (USACE 2007):

$$W_s = \frac{1}{18}\frac{(s-1)gd^2}{v}$$

Where,

g is acceleration due to gravity

d is a particle diameter

v is the kinematic viscosity of water

$s=\rho_s/\rho$ is the relative density, where ρ_s and ρ are the density of sediment and water respectively.

The settling velocity of the effluent sediment particles can be calculated based on the ambient conditions summarized in Table 1 for the marine water in the outfall area of Northumberland Strait, and the PSA data in Table 2 for effluent sediment properties that are based on Figures 1 and 2 and assuming no degradation of the particles.

Effluent sediments are typically biological flocs since they are organic in nature and are still significantly hydrated. The particle density of floc is normally in the range of 1,040 -1,080 kg/m^3 with a typical value of 1,060 kg/m^3 (Dr. Cliff Lange, Auburn University, pers. comm. 2019). In this study, the particle density of 1,060 kg/m^3 is assumed for the effluent sediment. The density of floc is slightly higher than marine water density (Table 1) but much less than the ambient marine sediment density which is normally about 2,650 kg/m^3 for sand material.

A field survey of the seabed sediment properties was conducted in late April – early May 2019 for the NPNS project. Five sediment samples were collected from the surface of the seabed in the outfall area. Base on the particle size analysis of the five sediment samples, the mean D_{50} value was 480 µm which can be classified as medium to coarse sand. This result indicates that fine material is scarce and does not settle in the area of the outfall location due to the nature of relatively high current speeds over time.

Table 1 Properties of Marine Water in the Outfall Area of Northumberland Strait

Parameter	Value	Unit	Note
Salinity	29.8	PSU	Measured[1] in range from 29.5 to 30.0
Density (ρ)	1,022.921	kg/m^3	calculated at 10° C (measured[1] in range from 7° to 10° C)
Acceleration (g)	9.8	m/s^2	-
Kinematic Viscosity (v)	0.000001308	m^2/s	calculated at 10° C
Current Speed	a) 0.08 b) 0.35	m/s	a) mean slack current speed based on field measurements at ADCP Station[1] (minimum hourly velocity every 24 hrs averaged for 30 days of deployment) b) mean current speed based on field measurements at ADCP Station[1]

1. Field survey conducted in May and June 2019

Table 2 Sediment Properties of Treated Effluent

Sediment Sample Location	Grain Size[1]		Note
	D_{50} (µm)	D_{90} (µm)	
Howe Sound Mill	15.3	58.8	See Figure 1 for distribution of effluent particle size
Crofton Mill	12.6	74.6	See Figure 2 for distribution of effluent particle size

1. Particle Density (ρ_s) is assumed to be 1,060 kg/m^3

Knowing the height of suspension of a particle above the seabed, the settling velocity can then be translated into the amount of time the particle is suspended in the water column during which currents could transport the particle horizontally. Assuming the height of the effluent jet plume in a range from 1 m to 5 m above the seabed (Table 3), the suspension time gives an indication of how long the sediment particle would take to settle to the seafloor and the horizontal displacement would be zero (no currents acting horizontally).

Based on the mean slack current speed (0.08 m/s) and the mean current speed (0.35 m/s) measured in the vicinity of the proposed outfall site, the transport distance of a sediment particle is then estimated from sediment suspension time and current velocity, where the suspension time depends on the settling velocity and the height above the seabed where a sediment particle falls from. The resulting estimated transport distances corresponding to particle drop heights of 1 m and 5 m, respectively, are shown in Table 3 for treated effluents from the Howe Sound and Crofton mills. These transport distances for the effluent sediment particles would be similar to the proposed NPNS replacement effluent treatment facility project.

Table 3 Estimated Transport Distance of Effluent Sediment Particles

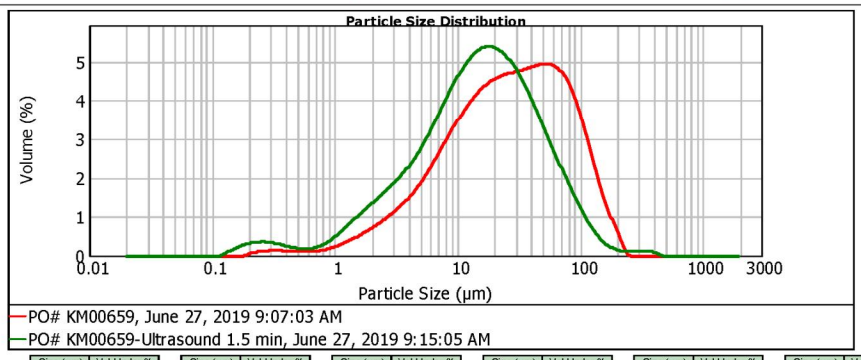
Effluent Sample Location	Particle Size (µm)	Settling Velocity (cm/s)	Suspension Time (hour)		Transport Distance for Current Speed 0.08 m/s (km)		Transport Distance for Current Speed 0.35 m/s (km)	
			1 m above bed	5 m above bed	1 m above bed	5 m above bed	1 m above bed	5 m above bed
Howe Sound Mill	D_{90}=58.8	0.0052	5.3	26.6	1.5	7.7	6.8	34.0
	D_{50}=15.3	0.0004	78.7	393.2	22.7	113.3	100.5	502.6
Crofton Mill	D_{90}=74.6	0.0084	3.3	16.5	1.0	4.8	4.2	21.1
	D_{50}=12.6	0.0002	116.0	579.8	33.4	167.0	148.2	741.0

MASTERSIZER 2000

Result Analysis Report

Sample Name: PO# KM00659-Ultrasound 1.5 min	**SOP Name:**	**Measured:** June 27, 2019 9:15:05 AM	
Sample Source & type:	**Measured by:** contract	**Analysed:** June 27, 2019 11:25:06 AM	
Sample bulk lot ref:	**Result Source:** Edited		
Particle Name: Wood Flour	**Accessory Name:** Hydro 2000S (A)	**Analysis model:** General purpose	**Sensitivity:** Normal
Particle RI: 1.530	**Absorption:** 0.1	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 9.86 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 0.761 %	**Result Emulation:** Off
Concentration: 0.0093 %Vol	**Span :** 3.672	**Uniformity:** 1.22	**Result units:** Volume
Specific Surface Area: 1.38 m^2/g	**Surface Weighted Mean D[3,2]:** 4.346 um	**Vol. Weighted Mean D[4,3]:** 25.525 um	

d(0.1): 2.532 um **d(0.5):** 15.281 um **d(0.9):** 58.649 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.010	0.00	0.105	0.00	1.096	3.91	11.482	40.37	120.226	98.16	1258.925	100.00
0.011	0.00	0.120	0.00	1.259	4.52	13.183	44.92	138.038	98.75	1445.440	100.00
0.013	0.00	0.138	0.06	1.445	5.28	15.136	49.67	158.489	99.13	1659.587	100.00
0.015	0.00	0.158	0.20	1.660	6.21	17.378	54.51	181.970	99.36	1905.461	100.00
0.017	0.00	0.182	0.43	1.905	7.30	19.953	59.38	208.930	99.50	2187.762	100.00
0.020	0.00	0.209	0.70	2.188	8.53	22.909	64.18	239.883	99.61	2511.886	100.00
0.023	0.00	0.240	1.01	2.512	9.91	26.303	68.85	275.423	99.69	2884.032	100.00
0.026	0.00	0.275	1.34	2.884	11.45	30.200	73.29	316.228	99.79	3311.311	100.00
0.030	0.00	0.316	1.65	3.311	13.15	34.674	77.46	363.078	99.89	3801.894	100.00
0.035	0.00	0.363	1.93	3.802	15.03	39.811	81.30	416.869	99.98	4365.158	100.00
0.040	0.00	0.417	2.17	4.365	17.13	45.709	84.76	478.630	100.00	5011.872	100.00
0.046	0.00	0.479	2.37	5.012	19.49	52.481	87.82	549.541	100.00	5754.399	100.00
0.052	0.00	0.550	2.54	5.754	22.13	60.256	90.49	630.957	100.00	6606.934	100.00
0.060	0.00	0.631	2.70	6.607	25.10	69.183	92.76	724.436	100.00	7585.776	100.00
0.069	0.00	0.724	2.88	7.586	28.40	79.433	94.63	831.764	100.00	8709.636	100.00
0.079	0.00	0.832	3.12	8.710	32.06	91.201	96.14	954.993	100.00	10000.000	100.00
0.091	0.00	0.955	3.45	10.000	36.06	104.713	97.30	1096.478	100.00		

Operator notes: *90 seconds ultrasound treatment was applied to disperse any aggregates in the sample.*

Malvern Instruments Ltd.
Malvern, UK
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Mastersizer 2000 Ver. 5.60
Serial Number : 34403-197

File name: PO# KM00659-Jun 27 2019
Record Number: 7
2019-06-27 12:00:45 PM

Figure 1 Particle Size Distribution Analysis on the Treated Effluent Sampled from Howe Sound Mill

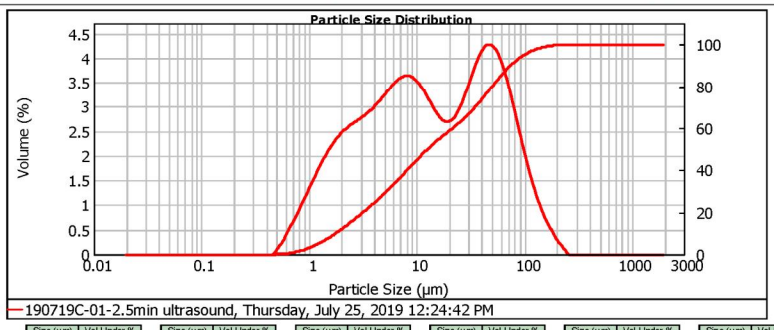
MALVERN INSTRUMENTS

MASTERSIZER 2000

Result Analysis Report

Sample Name: 190719C-01-2.5min ultrasound	**SOP Name:**	**Measured:** Thursday, July 25, 2019 12:24:42 PM	
Sample Source & type:	**Measured by:** Naeimeh	**Analysed:** Tuesday, July 30, 2019 4:48:31 PM	
Sample bulk lot ref:	**Result Source:** Edited		
Particle Name: Soil-2	**Accessory Name:** Hydro 2000S (A)	**Analysis model:** General purpose	**Sensitivity:** Normal
Particle RI: 1.100	**Absorption:** 0.7	**Size range:** 0.020 to 2000.000 um	**Obscuration:** 4.95 %
Dispersant Name: Water	**Dispersant RI:** 1.330	**Weighted Residual:** 1.848 %	**Result Emulation:** Off
Concentration: 0.0033 %Vol	**Span :** 5.791	**Uniformity:** 1.85	**Result units:** Volume
Specific Surface Area: 1.2 m²/g	**Surface Weighted Mean D[3,2]:** 4.991 um	**Vol. Weighted Mean D[4,3]:** 28.137 um	

d(0.1): 1.746 um **d(0.5):** 12.539 um **d(0.9):** 74.358 um



Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %	Size (µm)	Vol Under %
0.020	0.00	0.142	0.00	1.002	3.18	7.096	36.93	50.238	80.11	355.656	100.00
0.022	0.00	0.159	0.00	1.125	4.29	7.962	39.65	56.368	83.26	399.052	100.00
0.025	0.00	0.178	0.00	1.262	5.57	8.934	42.38	63.246	86.25	447.744	100.00
0.028	0.00	0.200	0.00	1.416	7.02	10.024	45.07	70.963	88.98	502.377	100.00
0.032	0.00	0.224	0.00	1.589	8.60	11.247	47.67	79.621	91.39	563.677	100.00
0.036	0.00	0.252	0.00	1.783	10.32	12.619	50.13	89.337	93.45	632.456	100.00
0.040	0.00	0.283	0.00	2.000	12.14	14.159	52.45	100.237	95.15	709.627	100.00
0.045	0.00	0.317	0.00	2.244	14.04	15.887	54.62	112.468	96.53	796.214	100.00
0.050	0.00	0.356	0.00	2.518	16.00	17.825	56.69	126.191	97.60	893.367	100.00
0.056	0.00	0.399	0.00	2.825	18.03	20.000	58.71	141.589	98.43	1002.374	100.00
0.063	0.00	0.448	0.00	3.170	20.11	22.440	60.76	158.866	99.04	1124.683	100.00
0.071	0.00	0.502	0.03	3.557	22.25	25.179	62.93	178.250	99.47	1261.915	100.00
0.080	0.00	0.564	0.17	3.991	24.46	28.251	65.28	200.000	99.77	1415.892	100.00
0.089	0.00	0.632	0.45	4.477	26.76	31.698	67.87	224.404	99.94	1588.656	100.00
0.100	0.00	0.710	0.89	5.024	29.16	35.566	70.69	251.785	100.00	1782.502	100.00
0.112	0.00	0.796	1.48	5.637	31.66	39.905	73.72	282.508	100.00	2000.000	100.00
0.126	0.00	0.893	2.25	6.325	34.25	44.774	76.89	316.979	100.00		

Operator notes: *190719C-01-2.5min ultrasound*

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Figure 2 Particle Size Distribution Analysis on the Treated Effluent Sampled from Crofton Mill

In conclusion, within the range of the particle sizes discussed for similar quality of treated effluent (i.e., with respect to Howe Sound and Crofton mills), the conservatively estimated sediment transport distance, depending on different assumptions on vertical suspension height of sediment from the effluent outfall discharge, are:

- For sediment particles dropping from a 1 m height, 90% of the sediment volume is expected to transport and deposit 1.0 km away from the outfall location.
- For sediment particles dropping from a 5 m height, 90% of the sediment volume is expected to transport and deposit 4.8 km away from the outfall location.

The above assumes no degradation of the particles transported. This is a very conservative assumption as most particles in the mill's treated effluent are organic in nature. The particle grain size is very small and, coupled with low density of the sediment material and long suspension times and transport distances, it is unlikely that sediment will build up in either the near- or far-field.

CLOSURE

This memorandum has been prepared for the sole benefit of Northern Pulp Nova Scotia Corporation. This memorandum may not be used by any other person or entity without the express written consent of Stantec Consulting Ltd. and Northern Pulp Nova Scotia Corporation.

Any use that a third party makes of this memorandum, or any reliance on decisions made based on it, are the responsibility of such third parties. Stantec Consulting Ltd. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made, or actions taken, based on this memorandum.

The information and conclusions contained in this memorandum are based upon work undertaken by trained professional and technical staff in accordance with generally accepted engineering and scientific practices current at the time the work was performed. Conclusions and recommendations presented in this memorandum should not be construed as legal advice.

The conclusions presented in this memorandum represent the best technical judgment of Stantec Consulting Ltd. based on the data obtained from the work. If any conditions become apparent that differ from our understanding of conditions as presented in this memorandum, we request that we be notified immediately to reassess the conclusions provided herein.

This memorandum was prepared by Shelton Liu (Ph.D., P.Eng.) and reviewed by Igor Iskra (Ph.D., P.Eng.) and Sam Salley (M.Sc.), and independently reviewed by Robert Federico (MPA).

Stantec Consulting Ltd.

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Project Manager and Senior Marine Scientist
Phone: (902) 468-7777
Fax: (902) 468-9009
Sam.salley@stantec.com

References:

UBC Institute of Mining Engineering, Result Analysis Report – Particle Size Distribution (sample: 190619B-09), June 27, 2019

UBC Institute of Mining Engineering, Result Analysis Report – Particle Size Distribution (sample: 190719C-01), July 31, 2019

US Army Corps of Engineers, September 2007: A Unified Sediment Transport Formulation for Coastal Inlet Application

June 17, 2019

ANALYTICAL REPORT

Particle Size Distribution Analysis
Project Name: Job #B9E4914
LEX File #: 08191128

Ms. Maryann Comeau
Maxxam Analytics Inc.
200 Bluewater Road
Bedford, Nova Scotia, B4B 1G9

Dear Ms. Maryann Comeau:

On May 31, 2019, LEX Scientific Inc. received one liquid sample for particle size distribution analysis. The requested work has been completed and the results are contained in this report.

If you have any questions about this report, please do not hesitate to contact me.

Yours Sincerely,

German Leal, B.Sc.
Laboratory Manager

291 Woodlawn Road West Unit B-12, Guelph, Ontario N1H 7L6
Phone: 519.824.7082 Fax: 519.824.5784 Toll Free: 1.800.824.7082
Email: lab@lexscientific.com Website: www.lexscientific.com

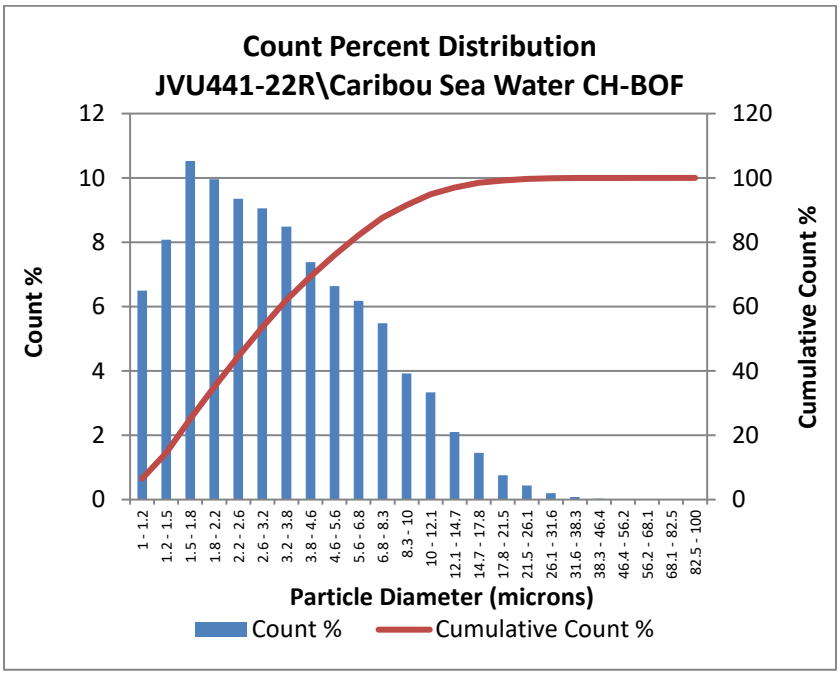
Methods

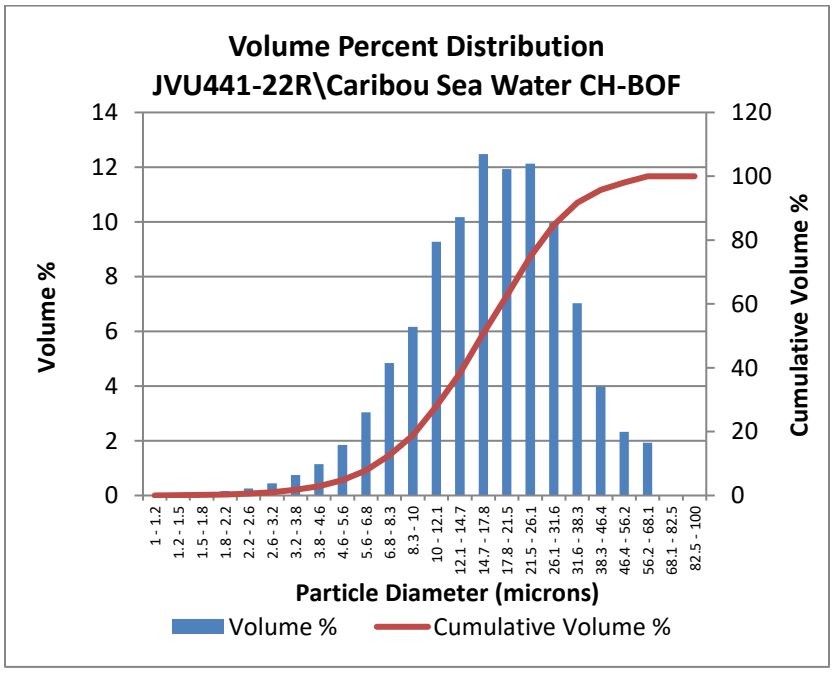
Particulates from the sample were analyzed using a computerized digital image system.

Results

Data applies for the reporting size range only. There are two types of materials suspended in the liquid. The large portion in size correspond to fibrous material.

Sample: JVU441-22R\Caribou Sea Water CH-BOF





Data for Sample: **JVU441-22R\Caribou Sea Water CH-BOF**

Diameter	Count			Volume	
(microns)	(Ct/mL)	(%)	Cumulative (%)	(%)	Cumulative (%)
1 - 1.2	399	6.49	6	0.0	0
1.2 - 1.5	497	8.08	15	0.0	0
1.5 - 1.8	647	10.53	25	0.1	0
1.8 - 2.2	612	9.96	35	0.2	0
2.2 - 2.6	575	9.36	44	0.3	1
2.6 - 3.2	556	9.05	53	0.4	1
3.2 - 3.8	521	8.49	62	0.8	2
3.8 - 4.6	454	7.38	69	1.1	3
4.6 - 5.6	408	6.64	76	1.8	5
5.6 - 6.8	380	6.18	82	3.0	8
6.8 - 8.3	337	5.48	88	4.8	13
8.3 - 10	241	3.92	92	6.2	19
10 - 12.1	205	3.34	95	9.3	28
12.1 - 14.7	129	2.10	97	10.2	38
14.7 - 17.8	90	1.46	98	12.5	51
17.8 - 21.5	47	0.76	99	11.9	63
21.5 - 26.1	27	0.43	100	12.1	75
26.1 - 31.6	12	0.20	100	10.0	85
31.6 - 38.3	5	0.08	100	7.0	92
38.3 - 46.4	2	0.03	100	4.0	96
46.4 - 56.2	1	0.01	100	2.3	98
56.2 - 68.1	0	0.01	100	1.9	100
68.1 - 82.5	0	0.00	100	0.0	100
82.5 - 100	0	0.00	100	0.0	100
Totals:	6,144	100%		100%	

Mean (Count): 4.4 µm
Mean (Volume): 20.1 µm

June 17, 2019

ANALYTICAL REPORT

Particle Size Distribution Analysis
Project Name: Job #B9E4405
LEX File #: 08191127

Ms. Maryann Comeau
Maxxam Analytics Inc.
200 Bluewater Road
Bedford, Nova Scotia, B4B 1G9

Dear Ms. Maryann Comeau:

On May 31, 2019, LEX Scientific Inc. received one liquid sample for particle size distribution analysis. The requested work has been completed and the results are contained in this report.

If you have any questions about this report, please do not hesitate to contact me.

Yours Sincerely,

German Leal, B.Sc.
Laboratory Manager

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Email: lab@lexscientific.com Website: www.lexscientific.com

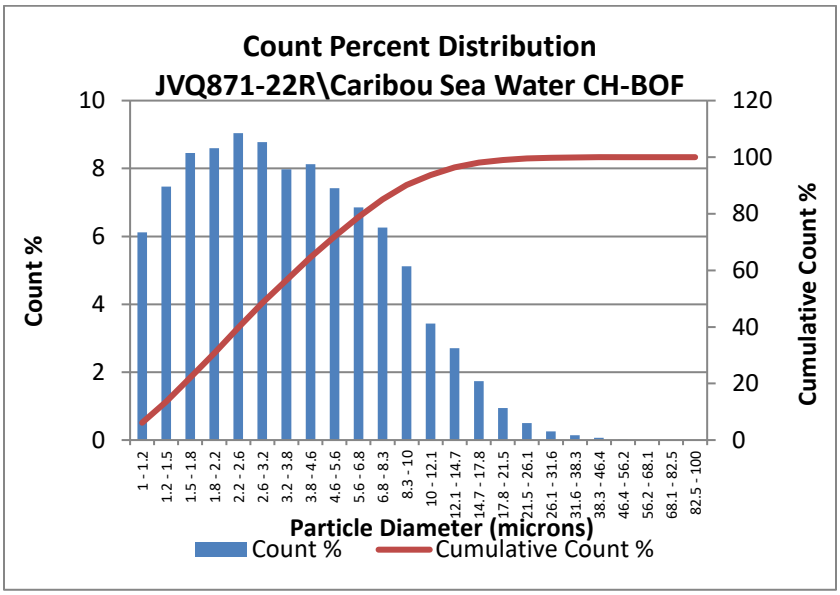
Methods

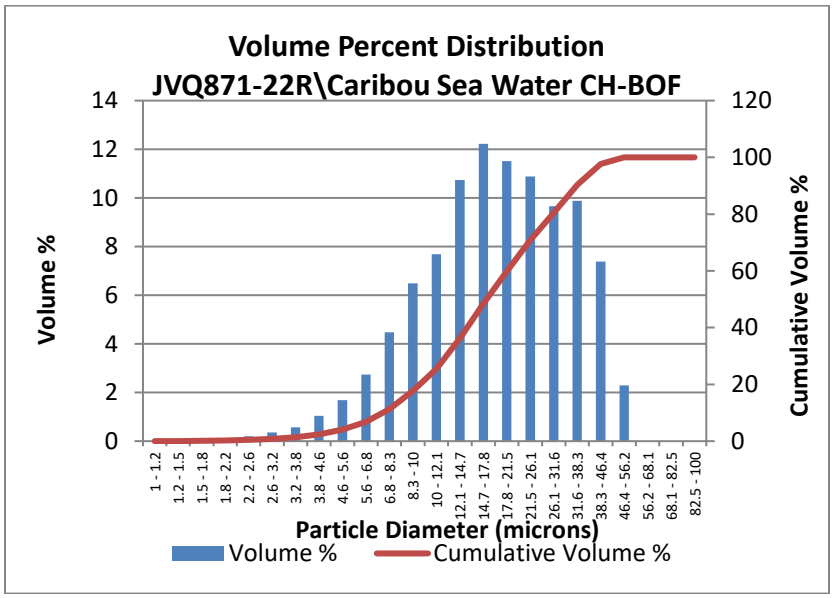
Particulates from the sample were analyzed using a computerized digital image system.

Results

Data applies for the reporting size range only. There are two types of materials suspended in the liquid. The large portion in size correspond to fibrous material.

Sample: JVQ871-22R\Caribou Sea Water CH-BOF





Data for Sample: **JVQ871-22R\Caribou Sea Water CH-BOF**

Diameter	Count			Volume	
(microns)	(Ct/mL)	(%)	Cumulative (%)	(%)	Cumulative (%)
1 - 1.2	633	6.12	6	0.0	0
1.2 - 1.5	772	7.47	14	0.0	0
1.5 - 1.8	874	8.45	22	0.1	0
1.8 - 2.2	889	8.60	31	0.1	0
2.2 - 2.6	934	9.04	40	0.2	0
2.6 - 3.2	907	8.78	48	0.4	1
3.2 - 3.8	824	7.97	56	0.6	1
3.8 - 4.6	840	8.13	65	1.0	2
4.6 - 5.6	766	7.42	72	1.7	4
5.6 - 6.8	709	6.86	79	2.7	7
6.8 - 8.3	647	6.26	85	4.5	11
8.3 - 10	529	5.12	90	6.5	18
10 - 12.1	355	3.44	94	7.7	25
12.1 - 14.7	279	2.70	96	10.7	36
14.7 - 17.8	179	1.74	98	12.2	48
17.8 - 21.5	98	0.95	99	11.5	60
21.5 - 26.1	52	0.50	100	10.9	71
26.1 - 31.6	26	0.25	100	9.7	80
31.6 - 38.3	15	0.14	100	9.9	90
38.3 - 46.4	7	0.06	100	7.4	98
46.4 - 56.2	1	0.01	100	2.3	100
56.2 - 68.1	0	0.00	100	0.0	100
68.1 - 82.5	0	0.00	100	0.0	100
82.5 - 100	0	0.00	100	0.0	100
Totals:	10,334	100%		100%	

Mean (Count): 4.8 µm
Mean (Volume): 20.7 µm